2. Two parallel plates are 0.50 cm apart and connected to a 9.0V battery.

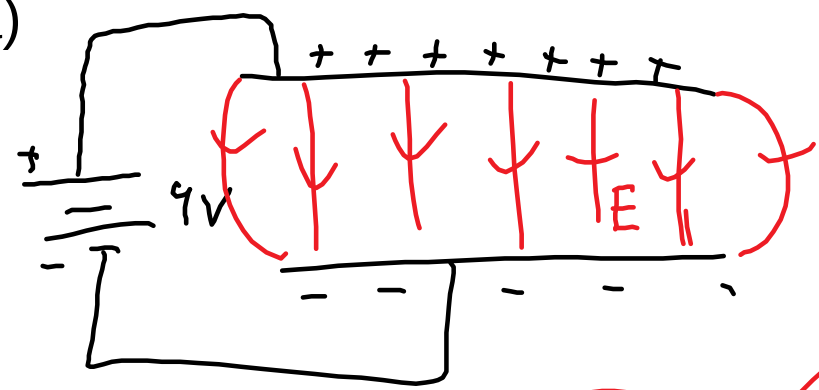
a) What is the electric field strength between the plates?

b) How much energy is required to move an electron from the negative plate to the positive plate?

c) How much work is done moving a proton 0.20 cm towards the positive plate?

e= 1.602 x 10^{-19} C (magnitude of the charge of proton or electron)

a)



$d = 0.50cm$

$$E = \frac{\Delta V}{d} = \frac{9V}{0.50 \times 10^{-2} m}$$

$$\Delta V = -Ed \qquad E = 1800 \frac{V}{m}$$

$$V = \frac{J}{C} = \frac{Nm}{C}$$

$$\frac{V}{m} = \frac{N\cancel{m}}{C\cancel{m}}$$

$$\boxed{1800\ \frac{N}{C}} \quad \left(\frac{N}{C} \equiv \frac{V}{m}\right)$$

b) $E_e = qEd$

or

$E_e = Vq = 90V(1.6\times10^{-19}C)$

$= \boxed{1.4\times10^{-18}J}$

$\boxed{= 90eV}$

c) $W = Fd = Eq\underline{d}$

constant

distance proton moves

$= 1800\frac{N}{C} \times 1.6\times10^{-19}C \times 2.0\times10^{-3}m$

$= \boxed{5.8 \times 10^{-19}\ J}$

in direction of $\vec{E}$

$950\,eV \rightarrow J$

$E_k = \frac{1}{2} m \underline{v}^2$

$950\,eV \left(\frac{1.602 \times 10^{-19}\ J}{1\,eV} \right)$

$= 1.5219 \times 10^{-16}\ J = \frac{1}{2} m v^2$

$v = \sqrt{\frac{2\,E_e}{m}}$

Velocity

$v = \sqrt{\frac{2(1.5219 \times 10^{-16}\ J)}{9.11 \times 10^{-31}\ kg}}$

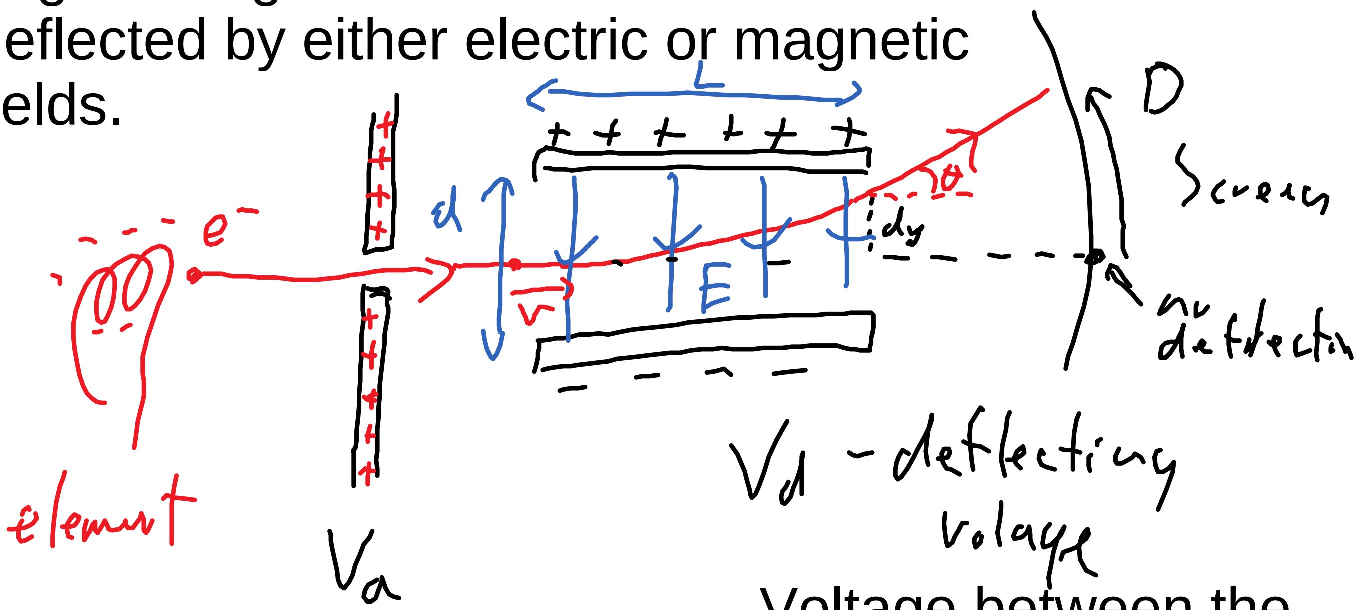
v

$$\boxed{v = 1.8 \times 10^{7}\ m/s}$$

CRT Lab Monday, April 4th
Investigation 8, p75 in the lab manual
Part 2, not use potentiometer, just 3 values
500V, 600V, 700V

CRT stands for Cathode Ray Tube
Cathode Rays are beams of electrons

Hot element (electron source) near a charged plate (accelerating plate) with accelerating voltage, V_a. The electrons are pulled off the element to the charged plate and accelerate to velocity, v. The charged plate has a hole in it that allows the electrons to go through. The beam of electrons is then deflected by either electric or magnetic fields.



Voltage between the parallel plates

What is the equation to find

a) Velocity of the electron after being accelerated by Va?

b) Electric field between the parallel plates due to Vd?

c) The acceleration of the electron between the parallel plates?

d) The deflection, d_y, as it leaves the plates?

$$E_e = E_K$$

$$V_a e = \frac{1}{2} m_e v^2$$

$$v = \sqrt{\frac{2 V_a e}{m_e}}$$

b) $E = \frac{V_d}{d}$

c) $a = \frac{F}{m} = \frac{Eq}{m_e} = \frac{V_d e}{d m_e}$

d) $d_y = \frac{1}{2} a t^2 + \cancel{V_{y_i} t}^{\,0}$

$t = L$

$$t = \frac{L}{v}$$

$$d_y = \frac{1}{2} a \left(\frac{L}{v}\right)^2 \qquad v = \sqrt{\frac{2 V_a e}{m_e}}$$

$$d_y = \frac{1}{2} \frac{V_d \cancel{e}}{\cancel{m_e} d} \left(\frac{L^2}{\frac{2 V_a \cancel{e}}{\cancel{m_e}}}\right)$$

$$d_y = \frac{1}{4} \frac{V_d L^2}{d V_a} \qquad \boxed{\begin{array}{l} D \propto V_d \\ D \propto \frac{1}{V_a} \end{array}}$$

Check in Lab

graph D vs Vd

D vs 1/Va

Check that they are

<u>linear</u>

- relate slopes.

Block 1-1

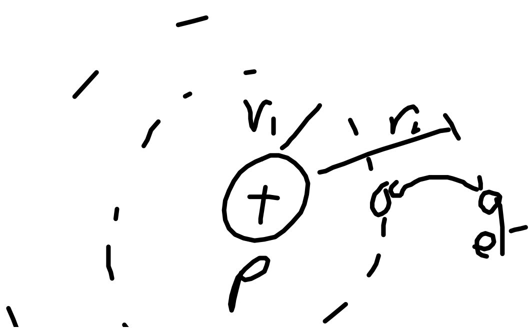
Eg. 1. An electron jumps from an orbital a distance 1.0×10^{-10}m to 5.0×10^{-11}m from a proton.

a) What is the electrostatic potential energy of the electron in each position relative to 0 at infinity?
b) What is the voltage at each orbital?
c) What is the potential difference between the outer and inner orbital?
d) What is the energy of the released photon? (energy difference)

2. Two parallel plates are 0.50 cm apart and connected to a 9.0V battery.

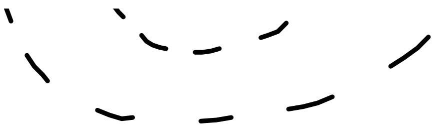
a) What is the electric field strength between the plates?
b) How much energy is required to move an electron from the negative plate to the positive plate?
c) How much work is done moving a proton 0.20 cm towards the positive plate?

e= 1.602×10^{-19} C (magnitude of the charge of proton or electron)



$r_1 = 5 \times 10^{-11}$ m

$r_2 = 1 \times 10^{-10}$ m



$$E_e = \frac{Kqq}{r} = \frac{9\times10^{9}\left(1.6\times10^{-19}\right)^2}{1\times10^{-10}}$$

$$E_e = \boxed{-2.3\times10^{-18}\,J \text{ outer}} \text{ and } \boxed{-4.6\times10^{-18}\,J \text{ inner}}$$

b) $V = \frac{KQ}{r}$ or $\frac{E_e}{q}$

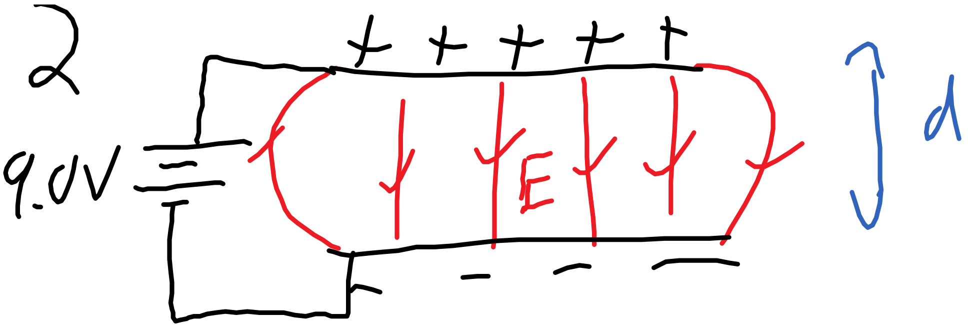
$V_{outer} = 14\,V$ $\quad V_{inner} = 28\,V$

c) $V_2 - V_1 = 28V - 14V = 14V$

d) $E_e = \Delta V q = 14\,Ve = \boxed{14\,eV}$

$$14\,V\left(1.6\times10^{-19}\,C\right) = \boxed{2.2\times10^{-18}\,J}$$

2



a) $\cancel{q}Ed = V\cancel{q}$

$$E = \frac{V}{d} = \frac{9.0V}{0.5 \times 10^{-2}\ m}$$

$$\boxed{E = 1800\ \frac{N}{C}}$$

c) $\underline{W = Fd = Eqd}$

or

$$\Delta E_e = Vq = 9.0V\ e = \boxed{9.0\,eV}$$

$$9.0V \times 1.6\times10^{-19}\,C = \boxed{1.5\times10^{-18}\,J}$$

c) $W = Fd = Eqd$

constant

$$W = 1800\,\frac{V}{C}\,(1.6\times10^{-19}\,C)(0.2\times10^{-2}\,m)$$

$$= \boxed{5.8\times10^{-19}\,J}$$

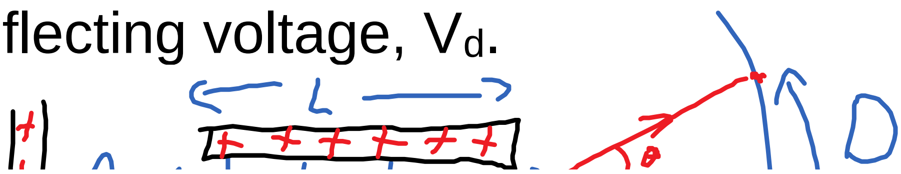
Cathode Ray Tube Lab
Investigation 8, p75 labbook
Formal lab - include the hypothesis we are going over right now.
Report is due April 8th, include the practice problems p80 in the labbook
Change to procedure, part 2, no potentiometer

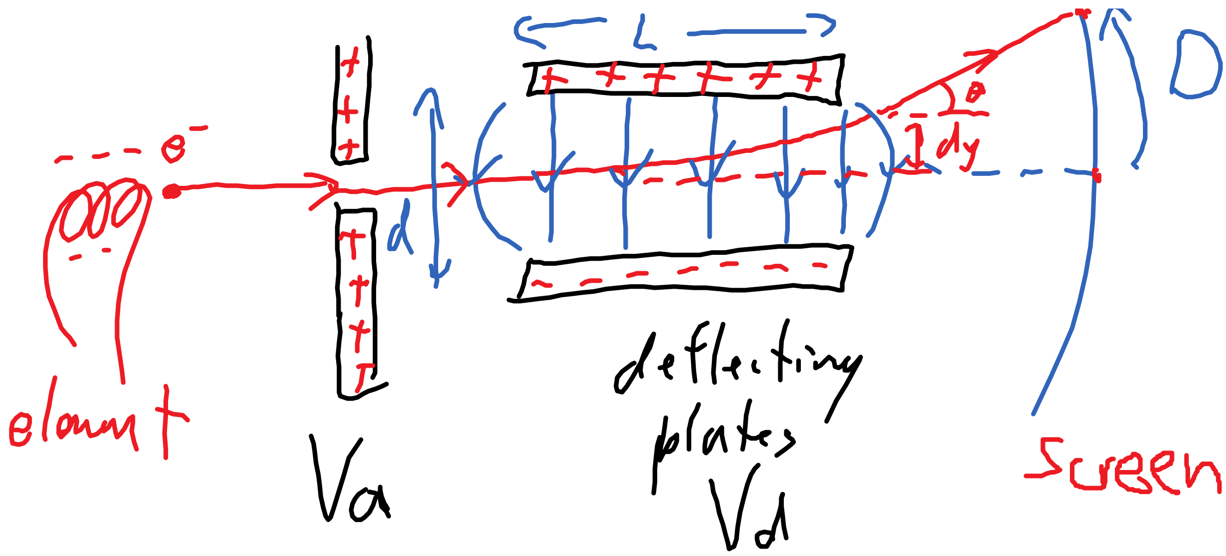
A cathode ray is a beam of electrons.

Hot element that is the electron source.

A positively charged plate with a hole in it, at the accelerating voltage, V_a.

Deflection. (some use magnetic fields) we will use parallel plates connected to batteries creating a deflecting voltage, V_d.





Lab: find the relationship
between D and Va and Vd

Derive the equation with respect to Va and Vd for

a) The velocity of the electron as it goes into the parallel plates.

V=energy/q
Electrical energy = kinetic energy
$V_a\ q = 1/2\ m_e\ v^2$
$v = \text{root}\ (\ (2V_a\ e)/m_e)$

b) The electric field between the plates.
$E=V_d/d$ (derived from $W=Fd = Eqd = Vq$)

c) The acceleration of the electron between the plates.
$a=F/m = Eq/m = (V_d e)/(m_e\ d)$

d) The deflection of the electron beam, d_y.

d) The deflection of the electron beam, d_y:

$d_y = 1/2\ at^2 + \cancel{v_{yi}t} \rightarrow 0$

$t = d_x/v_x = L/v$

$d_y = 1/2(V_d e)/(m_e\ d)(L/v)^2$

$v = \text{root}(\ (2V_a\ e)/m_e)$
So $v^2 = (\ (2V_a\ e)/m_e)$

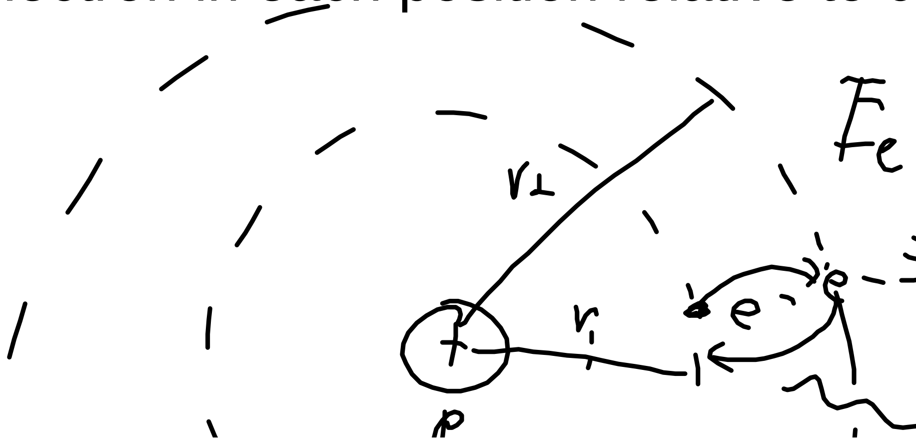
$d_y = 1/2(V_d \cancel{e})/\cancel{(m_e}\ d)\ \ (L)^2/((2V_a\ \cancel{e})\cancel{/m_e})$

$d_y = 1/4\ (V_d\ L^2)/(d\ V_a)$

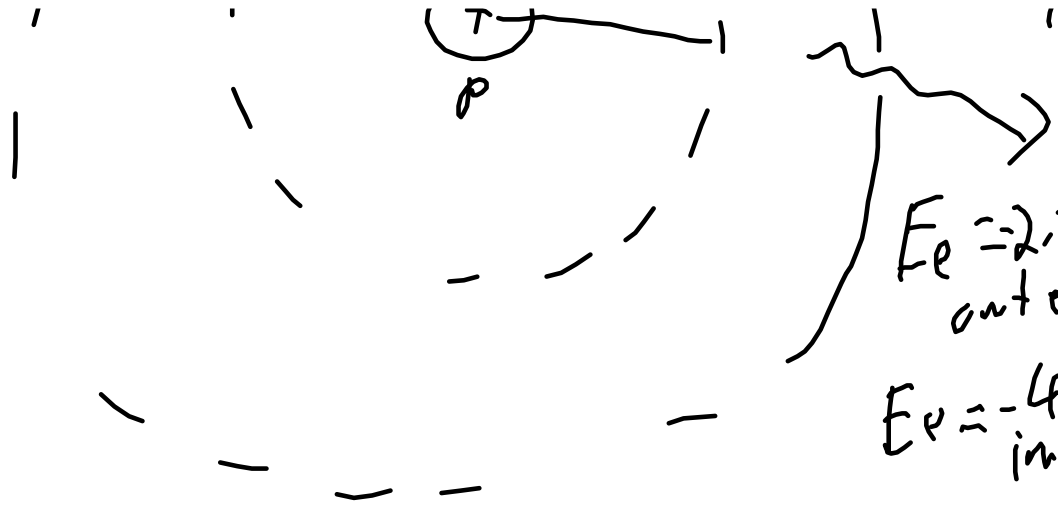
Big idea - if you graph D vs Vd is should be linear and D vs 1/Va should be linear

Block 1-3
Eg. 1. An electron jumps from an orbital a distance 1.0×10^{-10}m to 5.0×10^{-11}m from a proton.

a) What is the electrostatic potential energy of the electron in each position relative to 0 at infinity?



$F_e = \dfrac{kQq}{r^2} = \dfrac{9\times10^9(1.6\times10^{-11})^2}{1\times10^{-10}\,m}$



$E_e = -2.3 \times 10^{-18}$ J
outer

$E_e = -4.6 \times 10^{-18}$ J
inner

b) What is the voltage at each orbital?

V=Energy/charge = -2.3×10^{-18}J/-1.6×10^{-19}C

Or V = kQ/r = 14 V outer
28V for the inner

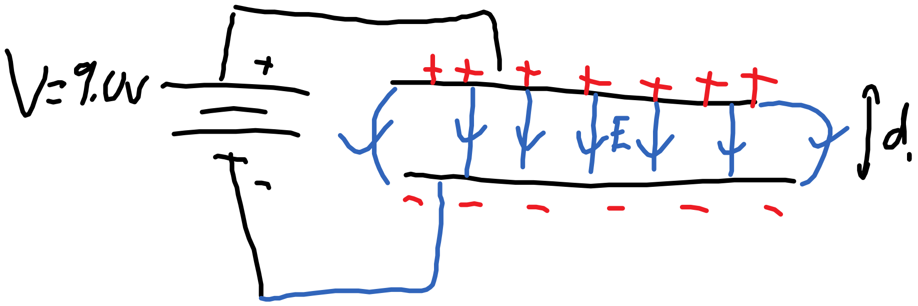
c) What is the potential difference between the outer and inner orbital?
Final - initial = 28V - 14V = 14V

d) What is the energy of the released photon? (energy difference)
Energy final - energy initial = $-4.6\text{x}10^{-18}$J-($-2.3\text{x}10^{-18}$J) = -2.3×10^{-18}J energy lost
Photon energy 2.3×10^{-18}J or 14 eV
Or use Energy = Vq

2. Two parallel plates are 0.50 cm apart and connected to a 9.0V battery.

a) What is the electric field strength between the plates?

$W = Fd = Eqd = Vq$



$E = ? = \frac{\Delta V}{d}$

E= 9.0V/0.5 x 10^{-2}m = 1800N/C

b) How much energy is required to move an electron from the negative plate to the positive plate?

Energy = Vq = 9.0eV = 9.0 V x 1.6x10^{-19}C = -1.4 x 10^{-19}J

c) How much work is done moving a proton 0.20 m towards the positive plate?

W = Fd = Eqd (note we can use this equation because the E field is constant)

W = 1800N/C 1.6 x 10^{-19}C x 0.2 m

W = 2.9 x 10^{-19}J

e= 1.602 x 10^{-19} C (magnitude of the charge of proton or electron)